Original

Before the Federal Communications Commission
Washington DC 20554

In the Matter of

Advanced Television Systems
and their impact on the
Existing Television Service

87-268

MM Docket No. 87-[redacted]

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The opinions expressed herein are those of the author only

November 30, 1988

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4. "HDTV," NHK Technical Monograph No. 32, June 1982.

5. EIA Letter to Chairman Patrick, June 30, 1988.

6. Schreiber reply to EIA Letter, August 2, 1988.

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1. EXECUTIVE SUMMARY

The background of the current controversy about ATV is discussed, with emphasis being given to the economic interests of the parties concerned and of the country as a whole, and to the economic consequences of the Commission's decisions. It is pointed out that both the Interim Report and Tentative Decision allow alternative media to adopt different ATV transmission formats and that this might well lead to the marketing of several kinds of mutually incompatible receivers. Such a situation is deemed highly detrimental to everyone's interests and the Commission is urged to take positive action to prevent it. In evaluating advice received, the Commission is requested to take account of the financial interests of the advising parties.

Although ATV is viewed as a primarily economic and political question, technology is shown to have a potentially significant role. It is now thought to be possible to design totally new systems that are more efficient in use of spectrum — that might allow for more stations in a smaller overall allocation — and yet might provide substantially improved quality in the home in the face of (typically) adverse transmission systems in today's terrestrial channels. In view of the fact that subjective picture quality in American homes is limited primarily by transmission defects, and not by the number of scan lines, the eventual adoption of such a spectrum-efficient system together with the eventual phasing out of NTSC emerges as the most important recommendation in these comments.

The influence of the choice of ATV transmission standards on the possible scenarios for the introduction of improved television is presented. The question of compatibility is discussed and it is pointed out that this is primarily related to the maintenance of audience share at the lowest cost by today's broadcasters. While this is highly desirable as the most direct way to maintain free and universal service, the public interest in this question can be satisfied by setting a cutoff date for NTSC sufficiently far in advance. The possibility of developing a friendly family of transmission standards for alternative media is presented, together with the vista of a superstandard from which the three probable production standards (in the US, Europe, and Japan) might be derived.

The Open-Architecture Receiver (OAR) is presented as a means of simplifying, but by no means eliminating, the question of setting ATV transmission standards. It also permits a great deal of flexibility in interfaces with other equipment and with respect to the introduction of further system improvements without obsolescence. The question of cost is discussed and it is concluded that the cost increment over the cheapest possible ATV receiver of the same picture size is likely to be very small or nonexistent. The baselessness of most objections to the OAR is pointed out.

Finally, a series of specific recommendations is made, the foundation for which is found in the requirement that the Commission act in the public interest. These recommendations include abandoning support for the NHK production standard, particularly for testing proposed ATV systems; making a definite plan for the orderly introduction of ATV, including the eventual phasing out of NTSC; requiring ATV receivers to be adaptable to a certain range of transmission formats; and encouraging alternative media to adopt a friendly family of transmission formats by such receiver regulations and by other appropriate means.

2. INTRODUCTION AND BACKGROUND

In this section, events leading to the Inquiry and the work accomplished thereunder up to this point are briefly summarized. Comments are made on the Interim Report [1] and the major decisions to be made by the Commission are outlined.

2.1 Origin of the Controversy

The Inquiry arose out of the perceived need of broadcasters for additional spectrum with which to compete with ATV provided by alternate media. In view of other claims on spectrum, particularly from land-mobile radio, broadcasters felt threatened and called for the Inquiry and a freeze on spectrum reallocation. Since it is broadcasters who provide free and universal TV service to the public, the Commission rightly felt that it was in the public interest at least to examine this matter.

It should be borne in mind that there is no sign whatever of a grass-roots demand for improved picture quality, and no evidence that the social role of television would be changed in any significant way by ATV. There *is* abundant evidence of a strong desire for, and willingness to pay for, the right kind of programs. This being the case, it is not in the short-term interests of broadcasters to invest in better quality except for the purpose of protecting their audience share. There is some possibility, however, that viewers would eventually learn to appreciate HDTV, especially as programs were produced that took advantage of its special capabilities. Therefore, the long-term survival of over-the-air broadcasting probably does require eventually equalling the picture and sound quality of alternative media.

An important point often neglected is that, in most cases, it is not bandwidth *per se* that limits picture quality actually observed in the home. Quality is limited at the present time primarily by signal degradation in the analog channel due to noise, echoes, interference, and distortion due to imperfect frequency response. Indeed, in the audience studies we conducted in December 1987 in which we compared NTSC and HDTV (1125-line wideband system), it became apparent that the perceived difference, as it might affect purchase decisions, between 525- and 1125-line systems in the studio was much smaller that the difference between 525 in the studio and 525 in the home. The moral of this story is that, unless effective steps are taken to improve transmission performance, most proposed ATV systems will *not,* in fact, make better pictures in typical American homes.

2.2 Interests of the Parties

As indicated above, the evidence is that viewers are interested primarily in more attractive programs. Since more than half of the TV households pay for cable service, and since this is usually for a wider program choice, (some do take cable because free broadcast TV is unavailable or of unacceptable quality) it is clear that this interest is quite strong. Secondarily, there surely would be *some* interest in higher picture and sound quality, particularly the latter, but the difference in quality would have to be very large to coax viewers to pay a large amount extra for it. As our studies have shown, the quality difference in the studio provided even by the 1125-line wideband system is marginal. For much of present-day subject matter, it is insignificant. The really large quality difference is found today between the studio and the home.

Aside from viewers, interest in ATV is almost exclusively based on economic considerations. For broadcasters, it is a question of audience share. For manufacturers, it is a question of potential profits from sales of professional equipment and receivers. For the country as a whole, it is a question of employment as well as the effect on the trade balance and the federal deficit.[1] Recently, attention has also been given to the possible effect of ATV on the semiconductor and consumer-electronics industries and on the general state of industrial competitiveness.

2.3 The Interim Report

The Interim Report reflects the interests of the companies and industries represented on the Advisory Committee; therefore, no statement that seriously offended any participant found its way into the final version. Thus, as expected and no doubt as intended, it represents a consensus of the views of the industry. While this is not a bad thing, particularly to the extent that the Commission believes its primary role is to adjudicate within the broadcasting industry, it tends to overlook the long-term interests of the country as a whole. It is clear to many outside observers that the most important aspect of ATV is what it may eventually to do the health of consumer electronics and semiconductor manufacturing. While many would hold that this is not the business of the Commission, surely it is the business of the government as a whole, since government decisions will have so much effect. It is not clear at present which government organs can or will take charge of this matter.

In spite of these limitations, the Interim Report is a good document. Most of the conclusions are sound, and evidently were acceptable to the Commission, since they formed the basis for the Tentative Decision. However, the Report did not resolve two conflicts. One is the desire of terrestrial broadcasters to set a single standard for all media (a natural desire since the over-the-air channel is technically the poorest) and the desire of alternative media to go their own ways. The second, which derives from the first, is the likelihood that there will be a multiplicity of ATV transmission standards used in the various media. Should several kinds of mutually incompatible ATV receivers appear on the market, ATV will have been struck a serious, if not fatal blow. (For those who wish ATV would go away, this would not be a bad outcome.) If this happens, everyone concerned, including unwary consumers who buy such receivers, will lose money. It is a situation to be avoided, if at all possible.

2.4 The Tentative Decision and Further Notice of Inquiry (FNOI)

The Further Notice [3] goes a long way toward reclaiming ATV as a subject for decision by Americans and not by other countries for us. Every American should applaud it. At the same time, we should recognize the limitations that it carries over from the Interim Report, namely the tacit approval given to incompatible developments of ATV in the alternative media and the consequent likelihood that mutually incompatible receivers will be put on sale.

The decision that ATV transmissions were to be viewable on today's receivers, either by simulcasting or by use of a receiver-compatible format, was preordained by the large installed

[1]The interests of the various parties were discussed at length in my Comments on the NOI. [2]

receiver base. No responsible person ever advocated anything else. However, it leaves unresolved the question as to how we are to get to a new system that might have real advantages over what we have now. The existing system suffers from a chronic spectrum shortage, primarily due to its extravagant use of bandwidth. At the same time, the average picture quality in American homes is a disgrace — a disgrace that will not automatically disappear with the adoption of a new system that simply has more scan lines.

The Commission stated its intention to give additional spectrum to existing licensees with the VHF and UHF bands for ATV purposes. The most important technical issue raised is the matter of the improved interference performance required for signals to be used in these newly awarded channels either as augmentation for NTSC transmissions in receiver-compatible implementations of ATV or as independent ATV signals in the simulcast implementations. Of the various proposals now before the Inquiry, only those of Zenith and MIT address this issue, and will be discussed below.

2.5 Choices Before the Commission

The primary choice is what kind of television system the country is to have after the changes about to start will have been completed. This choice cannot be avoided — it is the heart and soul of regulating in the public interest. It is a choice that cannot be left completely to a free market, since, by its nature, broadcasting can never be completely free. No one, except perhaps a libertarian here or there, advocates letting anyone who wants to broadcast to put up a station and transmit on any standard he pleases. Furthermore, the time scale required to develop and deploy a new TV system is much too long to allow a market of the Adam Smith[2] type to work. Companies that took a sufficiently long view would go out of business long before their products reached market.

In my view, the most important questions are:

1. Is the system of free and universal service to be maintained? If so, which entity will provide the service and what should the Commission do to ensure that that entity will remain economically viable? If maintaining that service involves regulating receiver compatibility or standards in other media, is the Commission prepared to deal with that?

2. Should we maintain a single standard of performance for all programs and for all media, or shall we permit or encourage a 2-tier or multi-tier system to evolve? In fact, do we need or want a theatrical experience each and every time we look at the tube? Perhaps 500-line quality or less is sufficient for much of the material that is transmitted, and 1000 lines is not nearly enough for some other subject matter. To what extent do we want some of this service to be 'free' and some of it paid for directly by the viewer.[3]

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[2]The original, not the current author.

[3]Of course, the viewer, partly as taxpayer, ultimately pays for all forms of television. It does make a difference, however, if the payment is exacted directly from the individual viewer or spread over a larger group by taxation or by incorporation in the price of advertised products.

3. What is to be done, if anything, about the extravagant use of spectrum by NTSC? If technologies exist or could be developed that could permit more stations in a smaller overall spectrum allocation and at the same time provide much better picture quality in the home, is it not the Commission's duty to make a plan to put such technology into place eventually?

4. How will the Commission deal with the economic dislocations that will inevitably accompany any change in the TV distribution system? How should the Commission deal with the intention of telephone companies to put fiber into every household and take over the job of TV signal transport from today's providers?

5. What, if any, is the Commission's duty with respect to the overall economic consequences of its decision making? Should the Commission deal with effects outside the TV broadcasting industry?

2.6 Technological Considerations

As in most public issues of consequence, the most important considerations are nontechnical. In this case, however, it appears that technology does have a significant role to play. The various media — terrestrial, cable, DBS, VCR's, and digital fiber — have different limitations on information transfer rate and therefore of deliverable signal quality. All of these media except fiber are analog and therefore subject to transmission degradation, terrestrial being worst and DBS being best in this respect. These media also have different bandwidth limitations. Terrestrial has a lot of channels that remain unused because of interference. Cable systems are generally full, but could provide more capacity by rebuilding. Single DBS channels are wider and have much less degradation than the other analog media, but the total number of channels available is much smaller.

The quality limitations for a given channel width as well as the vulnerability to analog channel distortions are inherent to NTSC. Therefore, *no substantial improvement in these factors in these channels is possible if NTSC is preserved.* Such preservation is required for receiver-compatible systems, and therefore these systems cannot improve picture quality very much in typical homes, no matter how much enhancement information is transmitted. Totally new systems, on the other hand, can be designed to give much better results.

Two kinds of receiver-compatible systems have been proposed. One kind, typified by ACTV from the Sarnoff Laboratories, hides the enhancement information within the NTSC signal. The other, typified by Glenn's Vista system, uses a second channel. It is probable that systems of the first type are even more vulnerable to channel degradation than NTSC itself, although this has to be examined on a case-by-case basis. Compatible systems that use an augmentation channel enshrine forever the inefficiencies of NTSC and its vulnerability to channel effects. Both kinds of systems do have the advantage that they give better quality than NTSC under good transmission conditions.

In addition to its vulnerability to channel degradation and to its rather poor quality per unit bandwidth even under good conditions, NTSC has very poor interference characteristics. Most of these NTSC limitations are due to the use of a very simple-minded receiver; some are

due to the state of technology at the time of system standardization. The art and science of signal processing has advanced a great deal since NTSC/1941 and NTSC/1953 set the monochrome and color standards. Technology has taken immense strides since then as well. It is both possible and practical to do much better. More sophisticated receivers can be made and sold at attractive prices, and totally new systems can be designed that provide much better picture quality in spite of channel defects. Finally, much better interference performance can be achieved so that more stations can be accommodated within an overall spectrum allocation.

The difficulty of using a totally new system that, of course, would be incompatible with NTSC receivers, is one of transition. The Commission recognized this in the FNOI by requiring that, for an initial period, existing receivers must be served with the same programs *either* by using a receiver-compatible transmission format *or* by simulcasting NTSC on one channel and ATV on another. The only implied limitation on the ATV signal is that it be channel-compatible.

In principle, either of these approaches could be used in a transition scenario to an ultimate high-efficiency system that actually delivered good pictures in typically imperfect channels. A requirement is that the intermediate, or 'bridge' system be a true technological bridge for both broadcaster and viewer, and not simply an improvement over NTSC that is intended to be discarded in a few years. A bridge system intended for early retirement will create another receiver-compatibility problem. When the time comes to discard it, along with the associated receivers and specialized studio equipment, we can expect a chorus of demands that all this equipment be useable with the next system as well. Thus, we shall continue to miss the opportunity to implement a really good system that would benefit everyone.

It should be plain from this argument that the simulcasting approach is much more likely to end up with a truly improved system, since the simulcast signal would be some version of the final system. As a practical matter, all ATV receivers that will be sold for many years must also accept NTSC. The simulcast receiver, therefore, can also be the receiver for the ultimate system, perhaps with an inexpensive add-on or plug-in component.

2.6.1 Compatibility of different ATV formats

It now appears virtually certain that we shall have different ATV formats in Japan, in the US, and in Europe, for both production and transmission. It appears likely that there will be different ATV transmission formats used by US terrestrial, cable, and DBS systems. A different digital fiber format seems a certainty. A questions arises as to whether it would be possible to make these various American ATV formats at least friendly enough so that inexpensive and high quality transcoding would be possible. From the work we and others are doing on subband coding, I now believe this is probably possible. This and the related question of friendly production standards are dealt with in Section 4.5

3. SPECTRUM ISSUES

Television is not simply about transmitting from one transmitter to one receiver. It is about 1300+ transmitters and 160+ million receivers. From the regulatory viewpoint, it is about allocation of spectrum in the public interest when there are more claimants than there is spectrum available to satisfy them.

3.1 Is there a Spectrum Shortage?

More than half the spectrum below 1 GHz is allocated to television. In this Inquiry, the broadcast industry was initially concerned about the possibility that some of this might be taken away. Land-mobile and rapidly growing cellular radio systems can use more, and there are other unmet needs (or wishes) as well. The Commission has the duty to make decisions about the relative importance to the public of the possible uses for spectrum. Beyond that, there is the question as to whether the various claimants are being as efficient in using the spectrum as modern technology allows. The most glaring example of possible inefficient use is the practice of not using more than half the channels in any locality because of interference conditions. In addition, stations on the same channel must be nearly 200 miles apart. There are additional 'taboos' in UHF having to do with receiver performance.

Some of these taboos could be eliminated by improved receivers (a receiver-compatibility problem) and some by improved antennas (an economic problem for some viewers). Co-channel spacing is partly an antenna problem (depending on location) but mostly a problem of system design. The FNOI points out that signals to be sent in the soon-to-be-assigned extra channels must operate properly with substantially reduced interference protection. If this is deemed practical for ATV signals, why is it not also essential for NTSC-quality signals?

3.2 Near-Term/Far-Term Considerations

The FNOI points out that different ATV scenarios have different near- and far-term implications for spectrum efficiency. If it is really possible, as stated by Zenith, to transmit HDTV in 6 MHz noncompatibly using the taboo channels, then such a system provides higher long-term efficiency than receiver-compatible systems that will require 1 1/2 channels permanently. The price is the temporary use of two channels.

An even more significant implication of the Zenith approach is the long-term viability of NTSC itself. The situation in which NTSC is being transmitted in some channels at high power and HDTV is being transmitted in other channels at lower power is, at least, peculiar. From the viewpoint of other claimants for spectrum, it provides as clear an example as possible of spectrum wastage. If all transmission were in the HDTV format, more stations could be accommodated in a lower overall spectrum allotment, making room for other services. Furthermore, if it is really possible to provide much better performance in the face of typical channel degradations, as I believe, then the all-HDTV format would give substantially better picture quality in typical homes.

3.3 Ultimate Spectrum Efficiency as a Guide to Standards Decisions

Since spectrum is a scarce resource, it would seem that transmission standards should be preferred that use it most effectively. The elements of effectiveness include two separate but related issues:

1. The number of stations that can be accommodated within a given overall spectrum assignment. This is a function of required D/U ratio for a given quality of reception.

2. The picture quality actually produced in the home under typical conditions and with a reasonably-priced antenna, per unit bandwidth. In addition to interference from other stations, this includes the effect of noise, echoes, and frequency distortion.

It is clear that today's taboo channels must be used in order to make substantial improvements in spectrum utilization. This cannot be done with NTSC. It is highly likely that it can be done with some noncompatible formats. The issue, then, is whether a transition scenario can be worked out that makes it possible to go to such a system eventually with minimum cost and dislocation.

4. ATV STANDARDS AND TRANSITION SCENARIOS

It should be understood that the reason why there is so much interest in this issue is because everyone concerned realizes that the standard selected will go a long way toward determining who wins and who loses in this next stage of television development. If it were a purely aesthetic issue, or one that could be decided on a completely technological basis, there would be much less excitement. Unfortunately, the public, which also has an interest in this affair, is not well represented in the debate. Since the Communications Act requires the Commission to regulate in the public interest, it is the Commission that has the responsibility for ensuring that consumers get a fair deal.

4.1 NTSC Compatibility

The Commission has, at least temporarily, protected the installed base of receivers (and, willy-nilly, VCR's) by requiring all broadcast ATV programs to be made available to NTSC receivers. In view of the fact that much better standards, according to the criteria mentioned in Section 3, are realizable, *the only valid public-interest reason for maintaining NTSC compatibility in ATV is to protect today's receivers.* Any decisions about NTSC, for example whether it should be modified or relaxed, should be taken with this principle in mind.

An important issue is whether today's receivers should be protected permanently. I think not. There is no guarantee of permanence with respect to any other product sold. We regularly buy new cars and appliances for improved performance or for less utilitarian reasons. We dispose of the old ones at very low prices even though there is a lot of use left in them. All we owe to today's receiver owners is that they should be able to use them for a reasonable period, comparable to or a little longer than their expected life.

We should also bear in mind that the demand for compatibility is not coming from the public. It is coming from broadcasters who, understandably, want to protect their audience share, and not unduly to increase their costs. Surely, if we threatened to black out NTSC receivers on January 1, 1989, we would hear from the public. If, on the other hand, we make a decision that NTSC shall be phased out in 7 or 10 or 15 years,[4] and promise to replace it with something much better, the public will very likely accept it. They would buy new receivers in that time anyway, and they can use the old NTSC receivers to play back tapes for decades to come. In all likelihood, they will also be able to buy relatively inexpensive set-top converters that surely will appear on the market as the cut-off date approaches. What we have to do is to devise a scenario that deals with the broadcasters' concerns about the cost of maintaining audience share.

4.2 Costs of ATV to Terrestrial Broadcasters

The most important element for the acceptance of a transition scenario is dealing with the legitimate concerns of terrestrial broadcasters. As in any other business, they must accept the not-so-novel idea that additional investments are required to maintain their viability. HDTV

[4] In Britain and France, the transition to PAL and SECAM from the earlier 405- and 819-line systems (France had HDTV and gave it up for color!) was successfully done by means of simulcasting for a period of about 20 years. Of course, the situations in those countries in 1965 was not the same as in the US at present.

is coming via the alternative media, since costs in those media will be moderate and the quality can be high. In the short run, broadcasters can compete in their traditional way — by providing a wide variety of attractive programs, and by adhering to the time-proven principles of free and universal service, with a strong dose of localism. They have a short-term advantage over every other medium in doing this. In the long run, they must be able to compete in picture and sound quality as well, since their programming advantages will lessen over time. As the alternative media grow, the latter also will provide a lot of attractive programs, and they may choose to make basic service so cheap that it will be essentially free. The latter action would take away the most important advantage from traditional broadcasters.

Studio costs are essentially independent of the particular HDTV system chosen. Every system calls for HDTV cameras, recorders, film scanners, outside-broadcast vans, and postproduction equipment. During the compatible phase, no additional programming expense[5] is involved whether the receiver-compatible or simulcasting scheme is used, since initially the same programs will be seen on all receivers. There will be an encoding or transcoding cost, since an NTSC signal must be produced from the HDTV production system, and this cost does depend somewhat on which production system is used.[6]

The main cost difference between the two schemes is the extra transmitter needed for simulcasting as opposed to the transmitter modifications, if any, needed for receiver-compatible transmissions.[7] The Zenith proposal indicates that a very low-power transmitter would be needed — essentially a linear amplifier — of the order of a few hundred watts. This is, indeed, a very low cost as compared with other costs, such as programming, which are a normal part of the broadcaster's expenses.

4.3 Incentive to Buy ATV Receivers

There is no evidence at all that a significant portion of the public will buy ATV receivers solely to see the same programs in higher technical picture quality. In fact, for many of the systems proposed, the incremental quality improvement in typical homes is likely to be negligible.[8]

This is the great weakness in the first step of the transition scenario embodied in the FNOI. Although this plan may be unavoidable, we should recognize that it probably will result in very slow market acceptance of ATV. It is more likely that ATV receivers will be bought by subscribers to alternative media for the purpose of seeing desirable programs not

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[5]Of course, the programs will have to be made in HDTV, and this will cost something extra, at least at first during the early part of the learning curve. Programs made in 35mm film should not cost extra.

[6]Clearly, a production system friendly to NTSC such as 59.94 Hz, progressively scanned, would be the cheapest to transcode, and would give the best quality. Programs made in film would have no transcoding cost, since they simply would be used with two different film scanners.

[7]Receiver-compatible systems that use an augmentation channel cost just about as much as simulcasting schemes. It is hard to see any advantage other than the use of 3 MHz extra rather than 6 MHz extra. With good enough interference performance, 6 MHz would be nearly as easy as to provide as 3 MHz.

[8]There are some who believe that a wide-screen display, achieved by adding side panels that *must*, for NTSC compatibility, be devoid of important information, will provide such an incentive. There is no evidence that this is true; I think it is highly unlikely. It is worth noting the the Europeans are not using this method to achieve their degree of compatibility between wide-screen HDTV and narrow-screen PAL. Aspect-ratio considerations are discussed in Appendix 4.

available otherwise, or as soon, as there is plenty of evidence that people are willing to pay for programs. The first entrepreneur who packages the price of the receiver with the price of the programs may be the first one who succeeds in selling ATV to the public.[9]

If programs sell receivers, what is needed is an imaginative scenario in which terrestrial broadcasters can afford to transmit special programs on a preferential basis in the channel initially used for HDTV in the simulcast mode. This cannot be done in the receiver-compatible scheme.

One way this might be achieved is to provide a separate 'window' in time for ATV broadcasts. At present, there is a succession of fairly short windows in time for new theatrical productions — theaters, cable, cassette, and free TV. Increasingly, a window is being provided for 'pay-per-view' as well. Another window could be provided for free ATV, perhaps simultaneously with one of the other windows. Admittedly, this is an extra expense, but recall that the broadcaster is being paid by the advertiser to induce the audience to watch. These early ATV viewers will be mostly upscale, and it may well be that they will constitute a distinct target audience for advertisers.

There is bound to be some extra cost to the broadcasters as they introduce ATV. If they are not willing to bear any increased cost at all, they run the substantial risk of losing significant audience share over a 10-year time period, unless ATV is a complete failure.

4.4 Relationship between Receiver and Transmission Standards

There is no incentive to broadcast unless there are receivers and there is no incentive to buy receivers until there are broadcasts. This is the classical 'chicken-and-egg' problem that plagued color TV. Compatibility did not help much. (I believe it actually retarded the acceptance of color by the public.) People did not buy color receivers to watch monochrome programs. They are equally unlikely to buy ATV receivers to watch NTSC.[10] In the color case, the problem eventually was solved by the investment of nearly $3 billion at today's prices by David Sarnoff, an entrepreneur of a type long since gone from the American scene.[11]

With the likely weak demand for receivers, the situation would be made much worse by fragmenting the already small audience by means of different standards in the various media, each associated with a different receiver, all mutually incompatible. This eventuality should be prevented at all costs if we are sincere about wanting ATV to be a success. There seem to be only two solutions — require all media to use the same transmission standard (the broadcasters' choice) or require all the receivers to be adaptable to the various standards likely to be used.[12] The latter certainly would be the public's choice provided the cost were not excessive. Such receivers are discussed in Section 5 and Appendix 4.

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[9]The experience of the French with *Minitel* may be instructive. The government *gave away* the terminals and thereby *Minitel* became the world's first successful videotex system.

[10]A much less costly way to get better NTSC reception is to buy an IDTV receiver or install some version of Faroudja's system.

[11]It is sad to visit the carefully maintained Sarnoff museum at the former research laboratories of RCA in Princeton, recently given away to SRI as part of the GE/RCA takeover. It is rather clear what David Sarnoff would have thought of that.

[12]If a prescribed range of formats were required to be decodable on all such receivers, that would provide an incentive for the alternative media to choose a standard within the range.

Some people believe that, in spite of what the alternative media spokesmen are clearly saying, that in the end they will choose the same standard as terrestrial broadcasters on account of economic necessity. I think this is unlikely. Companies act in their perceived self-interest, so they will choose standards that they think will be most appropriate for their intended mode of using ATV. Many alternative broadcasters are planning to use ATV, not principally to retransmit programs that they receive from networks and local TV stations, but to originate special programs for niche markets such as pay-per-view. In that case, they will want to differentiate their product, rather than make it look like an over-the-air program. At least some of these programs would be made specifically for the wide screen and with as high a resolution as possible in each medium. There is no reason for cable and DBS to limit themselves by imitating TV stations unless they have an (economic) incentive to do so.

4.5 A Friendly Family of Standards for all the Media

Based on proposed systems that use subband coding, such as those of Zenith and MIT, there is a possibility that a hierarchical family of standards[13] could be developed that would permit each medium to use a system that maximized its own performance, but at the same made possible very easy interchange among systems. Subband coding is inherently efficient, since the division of the 3-d spectrum of the signal into components makes possible the assignment of channel capacity to each component in accordance with its visual importance. The production system would have the most components (and therefore the highest resolution) and the over-the-air system the fewest, with DBS and cable somewhere in the middle. Down-conversion would simply discard components. Up-converted signals would not have such high performance, but at least the systems would be easily transcoded. The components actually used could be repackaged in each medium for best channel performance.

4.6 Production Standards

The extreme concern shown in other fora, by the parties involved in this Inquiry, over the selection of production standards is also due to the effect such a selection is likely to have on who wins and who loses. If it really didn't make any difference, it is most unlikely that we would have seen the 1125/30/60[14] system pushed on us with such vigor. Indeed, it is still being pushed by some, allegedly in the hope that there is some chance that a world-wide standard may yet come to pass. There is no longer any realistic hope that this will happen, if, indeed, there ever was.[15]

Intelligent design of a television system starts with the receiver technology, then selects the channel, designs the transmission system, and finally devises a production system. Of course, if one is making film, the production system comes first, but in that case, it would be

[13]It was Birney Dayton of Grass Valley who first suggested this approach during a discussion of production standards, I believe.

[14]In this paper, the designation A/B/C refers to a TV system with A lines/frame, B frames/sec and C fields/sec

[15]In retrospect, there never was much likelihood that the Europeans would have accepted a 60-Hz standard, since it would be all cost and no benefit to them, protectionist arguments aside. It would have been better if they had stated so in the first place, instead of carping about the quality of conversion from 1125 to PAL. Their current intentions in this matter are crystal-clear. To continue to pretend that there is any chance for world-wide agreement on this matter is couter-productive.

perverse to use anything but 24 frames/sec, progressively scanned.[16] The claim that it is possible, in principle, to convert between any two formats with good quality, is correct. This was demonstrated by NHK's 1125-to-PAL converter. However, there is a difference in cost depending on the relationship of the two standards. The easiest conversion, *by far,* is between standards that use the same field rate and in which the source system is progressive. It should be borne in mind that transcoders will never be made in very large quantity, so that the economies of scale that apply, for example to receivers, do not apply to transcoders.

The history of its development shows very clearly that the NHK wideband system was not designed as a production system.[17] If it had been, it would have used progressive scanning. It was clearly designed as a DBS system without storage so that the scanning standards of camera, channel signal, and display were all the same. The system was successfully demonstrated in that mode in 1978, using a transponder channel over 100 MHz wide. [4, p. 84] Evidently, that was deemed uneconomic, and so about 1982, development was started on a bandwidth-compression system, announced as MUSE in 1984. MUSE can be transmitted in a normal transponder channel, for which service it is well adapted. It was not originally designed either for cable or over-the-air transmission, in which services it would be expected to be worse than NTSC in its vulnerability to analog channel degradation.

The question of production standards cannot be avoided in the present Inquiry, even though the principal goal is to select ATV transmission standards. The candidate systems must be tested. Amazingly enough, there are those who are pressing to test all such systems with 1125/30/60 on the grounds that it is the only thing around. Actually, it is not the only thing around. The Bosch KLH-1000 camera, for example, works in a range of formats, including 1050/29.97/59.94 and 525/59.94/59.94. Since the proper design of a production system should come only after a transmission system is selected, it would be best to test each proposed transmission system with whichever production system it works best. If a single production system were to be forced on all candidates, then 24-frame film would be the most important, since film provides such a large proportion of prime-time programming.[18]

4.6.1 Program-interchange standards

The CCIR has no legitimate interest in production standards, which are an internal matter of the nations involved. However, the case for a CCIR-codified interchange standard, to replace or supplement film, which now serves as a *de facto* standard, is a good one. The

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[16]Today's HDTV cameras would produce significantly higher film quality if the horizontal scan frequency were kept the same and the vertical frequency were reduced to 24 Hz. The vertical resolution of the cameras would increase substantially and the motion rendition on the film would probably be better, since the 60-to-24 Hz down-conversion would be avoided.

[17]The massive report on this system [4] does not have a single mention of its use as a production system. Since it is intended, in Japan, that the HDTV service is to be entirely separate, with NTSC being maintained for terrestrial transmission, the question of its friendliness to NTSC apparently never arose during its development.

[18]In my opinion, 24-Hz progressive is a viable candidate for production for all media. It would make the best film. The transcoding cost would be negligible, since its signal could readily be made to 'look' just like that from an NTSC film scanner. The cameras would give higher vertical resolution, as mentioned previously. However, it would require motion-compensated interpolation for up-conversion to the ATV transmission format, and I find that acceptance of this kind of processing is not sufficiently widespread in the TV community at the present time. In time, with more demonstrations of good motion-compensated interpolation, I believe that this method will gain wide acceptance.

problem here, however, is the same as with production standards. If, for whatever reason, different countries use different transmission standards, the transcoding costs depend on which interchange standard is used. For the 50-Hz countries, neither 60 Hz nor 59.94 Hz is satisfactory, so there is no motivation for them to use it. We are simply not going to have a world-wide interchange standard, not matter how desirable that would be in theory.

The argument is sometimes made that the US must use 1125 in order not to lose its advantage in selling programs overseas. This argument, as far as I can tell from speaking to industry people engaged on a daily basis in this matter, has no foundation in fact. The technical format in which programs are produced has absolutely nothing to do with their salability — it is not even an issue often raised. US-made movies and TV programs enjoy world-wide popularity (like Levis, Coke, and Big Macs) because they express the American spirit, and not because of their format. Furthermore, the largest market for American theatrical productions is Europe, and the Europeans have made it as plain as possible than they are not going to use 1125. It is time to stop using this argument at all levels of American discussion, including the US Government.

4.7 A Superstandard?

Given the present situation with respect to plans for ATV in the US, Europe, and Japan, it appears that there will be three different production standards. This is not solely due to bull-headedness or simple protectionism on the part of those involved. It comes about because compatibility concerns have led to real differences in the transmission systems to be used in the US and Europe and because there are real costs associated with the use of an unfriendly source system. This being the case, it might be more productive to stop trying to attain the unattainable and instead turn our attention to a possible superstandard from which the three production standards, as well as film, could be derived.

One thousand lines is certainly not the last word in high resolution. In graphic arts, 200 to 1000 lines *per inch* is routine. Electronic still photography, an industry waiting to be borne, and moreover one in which the US is probably ahead of Japan through the efforts of Kodak and Polaroid, also requires more than 1000 lines. Computer graphics, CAD/CAM/CAE all could use more. There seems to be a substantial perceptual improvement between 1000 and 2000 lines.[19]

Looking ahead to the time when further progress in cameras and scanners makes it practical to deal with much higher resolution, it would appear possible to develop a superstandard in the neighborhood of 2000 lines progresssively scanned. The several production standards could be derived from the superstandard, and the latter could be used directly for applications requiring the higher resolution.

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[19]In our laboratory, we have been showing 2000-line images to visitors for the last year. These are display on a 20x20" Sony monitor using pictures scanned on a Scitex graphic-arts scanner. They invariably provoke a strong favorable reaction from visitors.

5. THE 'SMART' OPEN-ARCHITECTURE RECEIVER (OAR)

One thing that is certain about the future of television is that there is going to be a convergence between TV and computer technology. We are already seeing this happen all around us. A modern TV terminal is basically a TV receiver. Telco plans for fiber to the home depend on subscribers' willingness to pay for additional services not now being used, many of which will involve interfacing the TV set to other devices. Today's high-end TV sets are using an increasing amount of sophisticated chips, including frame memories and microprocessors.[20]

Less certain, but highly probable, is the existence of several different ATV transmission standards. What is absolutely certain is that all ATV receivers will cope with NTSC as well, and they almost surely will do this by upconverting the NTSC signal to the high-resolution display format. This requires a certain minimum computing power.

All this means that ATV receivers are going to do a lot of signal processing. Any engineer who graduated from school in this decade, faced with this kind of a problem, would use a bus-structured design.[21] Bus-structured systems, invariably used in computers, may be 'open' or 'closed.' An open architecture invites third parties to provide add-ons in the form of software and hardware to add functionality. It also facilitates interfacing with other equipment and transmission lines. Open architecture was responsible for the quick success of the IBM PC. This success led Apple to embrace open architecture in the MacIntosh. It is not a novel or radical idea. It is the normal way to design complicated systems today.

The proposal to use the OAR for ATV has met with a chilly response from many receiver manufacturers, although communication companies and computer companies have been more ready to embrace the concept. The response from the Electronic Industries Association was notable for the scale and character of the objections. These complaints were contained in a letter to Chairman Patrick [5] to which I replied [6]. My opinion about the EIA objections is that they are entirely without basis in fact.[22] There *is* a legitimate question of cost. ***There is no other legitimate objection to the OAR.*** This being the case, one has to ask what makes receiver manufacturers so uncomfortable with this concept? A partial answer to this question can be found in the traditional reluctance in well established industries to embrace new technology. This is part of the reason why the Japanese did so well after WW II when they were forced to rebuild their entire industry, and naturally used the most modern methods. We did not do the same, and suffered the consequences, for example in the steel industry. The TV industry itself has been notable in this respect. There was tardiness in abandoning vacuum tubes and in going to modern assembly methods.

There are other explanations for opposition to the OAR aside from concern about new (i.e., new to the opponents) technology. The commodity-type receiver now dominates the

[20]The MUSE receiver being designed by NHK will use a microprocessor for automatic channel equalization, and very likely for other purposes as well. There is already a fair amount of computery in programmable VCR's and cable-ready TV receivers.

[21]It is likely that ITT, manufacturer of digital chip sets for today's receivers, will go to a bus structure for greater flexibility and to permit software-based signal processing. Bus structures are also advocated for automobile electronic control systems and for 'Smart House,' a plan for introducing many new electronic services for residential application.

[22]At a meeting of the ATSC on this subject on October 24, 1988, I dealt with the EIA objections one by one. The EIA representative who followed me did not reply to a single argument that I presented, and I must therefore conclude that he cannot refute the points made.

market. It has become low tech, and, as such, difficult to make in the US at a profit.[23] The low cost associated with current receivers drove many US manufacturers out of the business and/or forced them to go off-shore for manufacturing. However, ATV receivers will not be made on cookie-cutters, at least for some time to come. They will be high-tech since there will be much more sophisticated signal processing (MUSE is a good example), there will be frame memories, and there will be scan conversion. There will be much more interconnection to other equipment, and probably to multiple signal sources. The OAR is the best way to deal with this complexity.

Another advantage of the OAR is that it makes it possible to improve the performance of the chosen ATV system in an evolutionary manner after inception. The rapid progress in TV system design being made now under pressure of the Inquiry will clearly not stop abruptly when an initial standard is selected. Improved components, particularly special signal-processing chips, will continue to come along. The OAR provides the means to incorporate these improvements in receivers whenever they become cheap enough to reach the market. A commodity-type single-standard receiver, by nature, cannot be adapted in this manner.

5.1 Cost of the OAR

In today's NTSC receiver, signal processing accounts for 10-12% of the cost, according to a statement made on November 17 by Peter F. McCloskey, president of EIA, to a meeting of the Commerce Dept. Advisory Committee on ATV, of which I am a member. Most of the cost of today's TV sets is associated with the picture tube, cabinet, and power supply. In ATV receivers, picture tubes will be much more expensive, partly because most of them will be large. Therefore, even if the OAR configuration materially raised the cost of signal processing (which I doubt it would) the total cost of the receiver would be hardly affected at all. The added complexity of ATV receivers is inherent in the signal and display formats that will be used. Today, however, complexity is not invariably associated with high cost. What we are proposing is to use a bus structure to deal with complexity, a step that adds very little cost, but enormously increases the flexibility for manufacturers as well as consumers.

The bus structure lends itself just as much to cost reduction as any other design principle. This paper is being typed on an IBM/XT which has been reduced in price from $4000 to about $1000 in the last 4-5 years. ATV receivers will be expensive at first, regardless of how they are built. Recall that monochrome receivers cost about $3000 at today's prices when first introduced in the late 40's, and color receivers cost about the same on the same basis in the 60's. ATV receivers will come to the market at about $3000, partly because that is what manufacturers seem to think early adopters will pay. As volume grows and the manufacturers proceed down the learning curve, the price will drop to a modest increment over the price of NTSC receivers of the same size. This could change with some breakthrough in display technology, which might reduce the cost of all kinds of large-screen receivers.

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[23] Many of the receivers 'made' in the US by foreign-owned companies import the boards and semiconductors.

5.2 The OAR and standards setting

The OAR is not an excuse for failure to set standards. It is a realistic response to the likelihood that there will be more than one ATV standard in the various media. Even if there were a single ATV standard, the OAR would still be useful for its flexibility and ease of interconnection. Standards for broadcasting should be set when there is enough information so that serious mistakes are unlikely. We have not reached that point yet, particularly as most proponents have not yet come to grips with the reality of transmitting improved pictures in today's channels.

With respect to the alternative media preferring no regulation of their formats, that is quite natural in view of the fact that these media have technically superior channels and want to take advantage of this situation to transmit superior pictures. It is hard to see how it is in the *public* interest to force a purveyor to market an inferior product to make sure it is no better than someone else's. To do so, the Commission would have to find that terrestrial broadcasting is the only way to preserve free and universal service and that its survival is threatened by better pictures in other media. Actually, its survival is already threatened by competition from alternative media using NTSC. The broadcaster's channel cannot be cleaned up if NTSC continues to be used. The best thing that the Commission could do to preserve the broadcasters, if picture quality in the home is really the issue, is to make it possible for them to go to a more robust transmission format.

Actually, the physical characteristics of the several media are sufficiently different so that somewhat different transmission formats are justified on technical grounds. For example, cable has an entirely different situation with respect to both co-channel and adjacent-channel interference and with respect to SNR. As discussed above in Section 4.5, it may well be possible to contrive a family of closely related standards for the different media so that transcoding among them would be very easy and that channel performance would be maximized. Of course, all the members of the family would be displayable on the OAR.

5.3 The OAR and multiport standards

The case for baseband RGB or Y/C inputs to TV receivers is so strong that they should have been made mandatory long ago.[24] Substantially better performance would be achieved when interconnection were used, as with VCR's and video games. They should be made mandatory now. However, they are not a substitute for the OAR, as they would result in a multiplicity of set-top converters when several different input standards are involved.

Standards conversion involves both the scanning standard and the modulation method. In the case of very similar scanning frequencies and modulation methods, the 'multisync' scheme used in PAL/NTSC receivers is appropriate. The scanning frequencies of the two systems are quite similar, and converting among the three modulation methods is rather simple. The net result is a receiver that has all the functions of two separate receivers for the two separate standards. Multisync is also used in some computer monitors, again for scanning rates that are

[24]Generally speaking, all manufacturers prefer the least regulation. However, a requirement that all of a class of products meet certain requirements *protects* the manufacturer who wants to incorporate some product improvement that is not immediately obvious to the consumer. A perfect example is the All-Channel Receiver Law, which made UHF economically viable.

not too dissimilar. A multiport approach is feasible in this case as well.

When scanning standards are very far apart, especially the horizontal scanning frequencies, the cost of changing the actual scan frequency of the display tube becomes prohibitive. In that case, scan conversion is better, in which the lower-frequency input signal is up-converted to the higher frequency for display. With this method, the display standard is never changed, no matter what line rate is used in transmission. This is the scheme to be used in the NHK MUSE receiver previously mentioned.

Upconversion for display is becoming increasingly common. It is one of the methods used to improve NTSC. in which the display is 525 lines progressive, 1050 lines interlaced, or even 1050 lines progressive. The *Eureka* receivers will have a similar scheme. It is now well established that to get the highest possible image quality with a given transmission standard, the highest possible standard should be used for the display. With up-conversion hardware already present, it makes sense to convert all input signals, no matter what the scan rate, up to the display rate in low-level signal-processing hardware, leaving the display rate unchanged. Of course, all receivers do not have to use the same display rate. The more expensive the receiver, the higher the display standard should be. Relying on the multiport approach when scanning standards are very different would require a dedicated set-top scan converter for each different signal. To restrict all systems and receivers to a narrow range of scanning standards, which is what is required to make the multiport concept cover all cases cheaply, would impose a severe restriction on the kinds of systems and receivers that could be developed.

6. RECOMMENDATIONS AND CONCLUSIONS

In this section, the proposed bases for decision-making with respect to ATV are given and a short list of actions that the Commission is urged to take is presented. Much of what I believe the government ought to do in this case is beyond the usual scope of Commission activities or, at least, requires cooperation with other government agencies. Some actions may require that the Congress give the Commission additional power or that it clarify powers that the Commission may now have under existing law. I urge the Commission to seek such action or such additional powers, should it concur with these recommendations.

6.1 Bases for FCC action

The primary basis for Commission decisions is the public interest. If the public could be adequately protected by a totally free market, there would be no need for an FCC. This interest certainly includes the maintenance of free and universal service on relatively inexpensive receivers as long as the public continues to give clear and convincing evidence that it wishes it. Within this generality, specific points of that interest can readily be identified.

1. *Overall economic effect.* The primary direct economic effect depends on the value added to TV products manufactured in the US as compared with the total value of all TV products sold in the US. A secondary, but perhaps equally important, effect is the viability of the domestic consumer-electronics and semiconductor industries. Rapid growth of ATV with an adequate proportion of domestic manufacturing is highly desirable. The current investment in NTSC equipment by industry and the public must be protected for a reasonable period, but not indefinitely. Today's broadcasters should have a reasonable opportunity to participate in ATV.

2. *Spectrum conservation.* There is, and there likely will continue to be, less spectrum available than could be profitably employed. Considering the very large proportion of the most easily used spectrum allocated to TV, a strong bias in favor of systems that deliver better pictures and sound from the largest number of stations to the largest number of receivers within the smallest overall spectrum allocation is entirely reasonable.

3. *Service quality delivered to the home under typical conditions.* The Commission should give more weight to quality in the home than in the studio. Today's NTSC studio quality is very good — the American public would be delighted to get it at home. Systems that deliver improved picture and sound under typical home conditions via the terrestrial broadcasting system should be given preference over systems that simply maintain today's performance in this regard.

4. *Flexibility over the life of the system.* The clearest aspect of today's technological environment is that it is changing very rapidly. Thirty years is too long to wait to get improvements to the public from the laboratory. The next television system should be able to be improved over time without obsolescence of

studio, transmission, or reception equipment. Receivers should be easily interfaced with the wide variety of equipment and services that is surely coming. Preferences should be given to new systems in which such flexibility is inherent.

6.2 Recommendations

These recommendations are entirely or partly within the rule-making power of the Commission. A broader range of proposals is contained in Appendix 7.

1. *Withdraw support for the NHK production standard and do not require its use for testing proposed systems under the current Inquiry.* If it ever was in our interest to support this system, it certainly is not now, especially in the light of the Tentative Decision and FNOI. In similar regard, advice tendered by organizations in which foreign-owned companies have an important voice, such as ATSC and EIA, should be given particularly careful scrutiny to see whose interests such advice would advance.

2. *Decide on a definite plan for the development and introduction of ATV, including the eventual phasing out of NTSC, with full consideration of the economic factors.* The plan need not select one of the proposed systems, but might well incorporate desired features from a number of different proposals. Some timing flexibility might be incorporated. Such a decision would remove some of the uncertainly that stands in the way of private investment. The US is the largest TV market in the world. A system guaranteed to be deployed in the US will surely attract the needed investment from foreign as well as domestic manufacturers.

3. *Require ATV receivers and peripheral equipment to be used with them, such as VCR's, to be adaptable to some range of ATV systems.* (Regulation should be just enough to achieve the objectives. In particular, scanning standards of the display should be optional.) This range should include the kinds of systems contemplated in the development plan discussed in Item 2. If a number of mutually incompatible ATV receivers appear on the market, advanced television will be struck a serious, if not fatal, blow. All participants, including the public, will lose money, and the economy will be the worse for it. This eventuality should be prevented, if at all possible.

4. *Encourage the alternative media to adopt transmission standards that are friendly to those the Commission is likely to adopt for terrestrial transmission.* The receiver-compatibility standards of Item 3 would be helpful in this regard. Additional steps might include spectrum assignments for DBS and for satellite transmission to cable head ends, interference requirements for cable, and the eventual promulgation of a family of digital ATV transmission standards for proposed digital media, when research in this field is sufficiently far advanced.

Appendix 1. Comments on Specific Questions Raised in the FNOI

(Numbers refer to paragraphs in the FNOI.)

4. *Comments on the Tentative Decision.* All Americans should applaud the Tentative Decision, as it goes a long way toward restoring control of the destiny of the US television system to American interests. The decision to require all ATV broadcasts to be displayable on NTSC receivers was inevitable, considering the very large installed base. However, it is very unlikely that many viewers will pay $3000 or more just to see the same programs in somewhat higher picture quality. I urge that this requirement be made temporary, and that, as soon as the situation permits, that broadcasters be allowed to use special programs to entice viewers to the new system.

In the long run, the public will be better off with an entirely new system, since typical picture quality can be improved and many more stations accommodated within the overall spectrum allocation. This transition should be encouraged as long as it does not lead to excessive cost to any significant portion of those involved.

5.1 *The Interim Report.* The interim report leaves unresolved the questions of multiple ATV standards and mutually incompatible receivers. These questions should be resolved.

5.2 *Systems that operate under strong interference conditions.* In Appendix 2, we discuss systems being developed at MIT that permit reliable operation under strong interference. Our preliminary results indicate that we can successfully transmit in the presence of an interfering NTSC signal 9 dB higher than our signal. If all signals used our coding method, we would need a D/U ratio of 9 to 12 dB. These are tentative results.

5.3 *Bandwidth for HDTV.* Since we advocate eventual phasing out of NTSC, the transition scenario we favor is the one most likely to lead to this result. Simulcasting, using 6 MHz each for the ATV signal and an unmodified NTSC signal, as proposed by Zenith, seems best. Systems that use an augmentation channel should bear the burden of demonstrating that they can serve as a bridge to a final spectrum-efficient system.

5.4 *Relax or repeal NTSC?* Since NTSC will be with us for some time, it is worthwhile to improve the picture quality as much as practical, even if this takes some modification of standards. The goal, however, should be to phase it out.

5.5-5.6 No comment.

10. *Standards for terrestrial ATV.* I believe that 6 MHz will be shown to be adequate for very good quality pictures delivered to the home under typical channel conditions.

12. *Simulcasting or compatibility.* We are developing both kinds of systems, but

on the grounds of spectrum efficiency and good picture quality in the presence of poor channel conditions, we favor simulcasting.

14. *Multiple standards in the various media.* We discussed this in the main part of the comments. Mutually incompatible ATV receivers on the market may well be the death of ATV, and should be avoided.

15. *Eureka compatibility.* The Europeans call their system compatible. Viewers need a satellite converter, and the plan is to put the required additional circuitry in the box so that conventional PAL receivers can be used.

18. *Aspect ratio.* See Appendix 4 for a discussion of this very important issue.

19. *Transition schemes.* The burden of proof that a system facilitates the transition to the ultimate system lies with the proponent. Unless the receivers of the bridge system can be used in the final system, there will be a problem with public acceptance, or else another reverse compatibility problem will be created.

21. *Production standards.* This issue cannot be avoided, even if the goal is to determine a transmission standard only. See Section 4.6.

29. *The MIT systems.* In Appendix 2, we discuss new versions of our systems having better performance in poor channels.

57, 63. *Required D/U ratios.* It appears that both the Zenith and MIT systems can operate at very low D/U ratios, and thus permit use of taboo channels for either augmentation information or an independent HDTV signal. Both are discussed in Appendix 2.

81. *Conclusions as to conditions under which extra spectrum is available.* We believe these conclusions are sound. However, they do not proceed to the logical next step as to what to do about NTSC. If HDTV is possible in 6 MHz at low power with good protection against channel defects, while NTSC requires high power for inferior pictures, the argument for maintaining NTSC indefinitely is quite weak. A study is called for that assumes all transmissions are in the same robust format and can operate at much lower D/U ratios than NTSC. The question is, how much overall spectrum allocation is then required to accommodate some increase in the total number of licensees? If this total amount of spectrum is substantially smaller than that now allocated, action seems called for.

82. *Compatibility in the transition period.* If it can be shown that much better performance is possible with totally new systems, then the goal should be to phase out NTSC within a period somewhat longer than the expected life of NTSC receivers. Everyone could then make the transition in the context of